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ART. VI. — *Organic Chemistry in its Applications to Agriculture and Physiology*, by JUSTUS LIEBIG, M. D., Ph. D., F. R. S., M. R. I. A., &c. Professor of Chemistry in the University of Giessen. Edited from the Manuscript of the Author, by LYON PLAYFAIR, Ph. D. *First American Edition, with an Introduction, Notes, and Appendix*, by JOHN W. WEBSTER, M. D., Professor of Chemistry in Harvard University. Cambridge : John Owen. 1841. 12mo. pp. 436.

THIS treatise makes a contribution to the cause of an improved Agriculture, of extraordinary value. It has been received with great interest in England, and will be read with equal eagerness by a large portion of our own people. Intelligent minds among us are everywhere awake to the immense and universal importance of the subject to which it relates. As a practical art, involving necessarily the existence of all other arts, and directly the uses and aids of many of them, the importance of the agricultural art cannot be overestimated. In an economical and political view, with the exception of the intellectual and moral interests of the community, which are also in some degree in abeyance to it, it is obviously by far the most important of all its interests, — the department of its industry which most deserves the attention of the patriot, the philosopher, and the philanthropist, as the means of subsistence, and comfort, and the foundation of national wealth. Extensive as are the commercial enterprise and the manufacturing industry of Great Britain, yet her agricultural interests far transcend them. In France, more than one hundred and twenty million pounds of sugar are annually produced from the soil, where, little more than thirty years since, not a pound was grown ; to say nothing of her products in silk and wine, which are in proportion. It is easy to see what a stake she has in agriculture. In China, a nation almost exclusively agricultural, for her various manufactures are mainly concerned in the products of her agriculture, where, besides her vast exports, more than three hundred and thirty millions of people are subsisted upon these products, we gather some impression of the immense importance of this art. There, likewise, the art has been carried to a higher perfection than in any other part of the

world. Among ourselves it would be vain, in the present youth of the country, to attempt to calculate the extent to which the art is destined to be carried. The forthcoming census of its agricultural products will exhibit results, which will excite universal surprise. An annual crop, in the Southern States, of more than 2,000,000 bales of cotton, of 249,000,000 pounds of sugar in Louisiana, of 42,000,000 bushels of Indian corn in Tennessee, of 18,000,000 bushels of wheat in Ohio, and more than 10,000,000 pounds of maple sugar in New York, great as these results appear, are yet only the first steps in the progress of this gigantic interest.

These facts show how essentially agriculture concerns the condition of the whole country. This interest, likewise, is certain to increase in an equal ratio with the growth of her population ; and let her commerce be ever so extended, or her manufactures as numerous and improved as invention and skill and art can make them, yet they must always be subsidiary to her agriculture. It is her agriculture which freights the barks of commerce, and drives the wheels and spindles of her manufactories in their rapid and infinite gyrations. At her breasts, without a single exception, the whole of the human family are to be sustained, nourished, and comforted.

The perfection of agriculture, as an art, implies the obtaining the greatest amount of product from the earth, with the least injury to the land, and at the least cost of labor. It has been often remarked, that the actual productive powers of an acre of land have never yet been fully tested ; the maximum of product has not been reached. Magnificent and surprising results have been attained, but in no case can it be said, with confidence, that more might not have been effected. In general, the agricultural art falls far below the condition of productiveness and improvement, which it might obviously attain ; and the aversion among farmers to change their established habits, and the slowness with which agricultural improvements of great and decided advantage extend themselves, even into neighbouring districts, are well known and sufficiently remarkable. Something of this has been owing to the stationary habits of farmers, to a want of education, and neglect of reading and inquiry necessarily growing out of this ; and much to prejudice, the natural child of ignorance, against scientific suggestions and the application of

science to an art, which, so far as they are concerned, is wholly of a practical character. This prejudice against the applications of science to agriculture, or to what in vulgar parlance is called *book-farming*, has, we confess, found some natural encouragement in the fact, that many persons, wholly destitute of practical knowledge and skill, have undertaken to apply purely theoretical rules, without regard to differences of soil, climate, nature of the crop, and nameless circumstances by which the application of these rules should be varied, or might be rendered unseasonable or futile ; and that, in truth, many persons have undertaken to make books, and to give directions in husbandry, who were grossly ignorant of its great principles, and possessed little knowledge of its various practical details and rules. It must, at the same time, be admitted, that science has as yet accomplished but little ; and that, beyond that knowledge which any intelligent, practical, and experienced man easily and almost necessarily acquires of soils, manures, vegetation, and crops, little has been ascertained of a practical value ; and the profound secrets of vegetable life, or what is properly termed *vital action* in vegetable organism and growth, remain in all their original abstruseness and mystery. The little success, therefore, which scientific men have had in their attempts to resolve and explain them, and especially the little practical utility which has come from their theoretical explanations, have created, with the purely practical, a prejudice against such inquiries, as invincible as it is unworthy of sensible men.

Yet it will not be denied, in this case, that we know as much of vegetable as we know of animal life. Anatomy may be termed an exact science ; it is to a great extent matter of sensible observation and measurement ; but the operations in the human organism, which are strictly vital, are altogether undisclosed. We know in truth as much how the stems and leaves and fruit are formed and perfected, as we know how the food, which we receive, is converted into blood, and serum, and bile, and muscle, and fibre, and tendon, and bone ; and we know no more. Shall we despair of going further ? By no means. There seems, indeed, in this case, to be a limit to inquiry ; an impassable barrier, where human sagacity and inquisitiveness are at once repelled ; the darkness is intense before, above, and around us, and the mere rush-light, which we hold out to guide us, serves no

purpose but to render this darkness visible. Shall we then be discouraged in all attempts at further advancement? Not at all. It may be indeed that we have reached the end of our line; and that, until new endowments are bestowed, the mind can soar no higher in its flight. But with equal, nay, with much more reason may we suppose, that the cause of failure is not so much attributable to the limitation or impotence of our faculties to proceed further, as to the imperfection or error of our modes of approach and inquiry. The philosophical mind, valuing truth and knowledge as the highest of all attainments, will never rest satisfied with present acquisitions; will regard that which is conceivable as knowable; like a vigilant and skilful officer before a besieged fortress, whose direct approach is precluded, will be continually seeking some private or concealed mode of access; or, like the man in the Scriptures knocking at his neighbour's door at midnight, and hoping presently to be heard for his importunity.

The immense importance and value of knowledge in this case no sensible man can doubt. If knowledge and science are useful in any art or department of business, why should they not be in agriculture, an art which involves many others, and which in its success combines the influence and operation of more elements than any other? It is well ascertained that certain plants will grow only in certain situations, and under certain circumstances; that different soils have different properties, prejudicial to the growth of some plants, favorable to the perfection of others; in some cases distinguished by an exuberant fertility, in others by an almost incurable barrenness, but yet in most cases capable of modification, remedy, or improvement; that the operation of various manures is various; and that their efficiency or injury depends upon their condition, preparation, or modes of application. It is equally well ascertained, that by some modes of cultivation, double the produce is obtained on the same land that is obtained under a different cultivation, and the land, at the same time, placed under a progressive improvement. It is ascertained that by the application of gypsum, or potash, or soda, or salt, or various animal substances, an extraordinary productiveness follows, and the crops are often trebled and quadrupled. How shall we pretend, then, that there is not here the most ample room for the application of science in the resolution of these remarkable facts, and in profiting by these remarkable

means for the improvement of the soil and the increase of its productiveness ? Separate, however, from the obvious utility of such inquiries, it is difficult to conceive of subjects more interesting to a philosophical curiosity than all those connected with animal or vegetable life and growth ; for what in nature is more wonderful than the birth and progress of a human being, or the germination of a dried seed and its advancement to the perfection of its uses and fruits ?

There are besides grounds of encouragement in this case, which the philosophical mind will duly appreciate. In the ordinary course of nature there is no such thing as accident or miracle. As far as man's sagacity has penetrated into the material world, — and of the spiritual world, we know nothing but by divine revelation, — all the phenomena of nature are found to proceed upon fixed principles and laws, and to be the results of nicely established and well balanced, compounded, and adjusted influences and forces. Many of these operations man is capable of imitating, and the most extraordinary results are obviously at his command. We cannot have a doubt, therefore, that the most recondite as well as the most familiar operations of nature are all the result of established principles and laws. Many of these laws we have already ascertained, and they are of daily application and use in the common business of life. How much further we may proceed in the discovery of them, time only can tell. As yet we have only placed our foot on the first step of the threshold. It is not an idle nor criminal presumption to seek to penetrate further into the temple of nature, until perhaps we may reach the Holy of Holies, where the Creator sits enthroned in his effulgence, and where we may adore him in the full blaze of truth.

Professor Liebig illustrates the spirit of which we speak. He is a bold inquirer of nature for the laws which govern her operations. He is for explaining the phenomena of vegetable life and growth upon the established principles of chemistry, as far as their application can be traced ; and he is not willing to take a general answer where a particular answer can be obtained. He does not feel satisfied to be checked in his inquiries under the presumption of inexplicable mystery, when further inquiry would untie the Gordian knot, and show that some of the problems, hitherto considered most difficult, are perfectly explicable upon the established principles of chemical science.

“ A rational system of agriculture,” says he, “ cannot be formed without the application of scientific principles ; for such a system must be based on an exact acquaintance with the means of nutrition of vegetables ; and with the influence of soils and the action of manure upon them. This knowledge we must seek from chemistry, which teaches the mode of investigating the composition, and of studying the characters, of the different substances from which plants derive their nourishment.” — p. 7.

“ Innumerable are the aids afforded to the means of life, to manufactures and to commerce, by the truths which assiduous and active inquirers have discovered and rendered capable of practical application. But it is not the mere practical utility of these truths, which is of importance. Their influence upon mental culture is most beneficial ; and the new views acquired by the knowledge of them enable the mind to recognise in the phenomena of nature proofs of an infinite wisdom, for the unfathomable profundity of which human language has no expression.” — p. 6.

The work is devoted to an explanation of the proper food of plants, and the modes in which, and sources from which, they receive this nourishment. Connected with these matters, come, of course, the value and uses of manures, and the true art of culture. These subjects are all obviously of the highest importance ; and it is exceedingly interesting to see how a mind so powerful and learned discusses them. The author speaks with just respect of that distinguished man, the late Sir Humphrey Davy, who first taught systematically the application of chemical science to agriculture ; and he shows himself not an unworthy pupil of so eminent a master. We can do but imperfect justice by an abstract of his views ; yet it is all for which we have room.

The elements or constituents of all plants are carbon, water, (or its elements, hydrogen and oxygen,) nitrogen, and some earthy or alkaline salts. The food of plants can be received only in a gaseous or soluble form, and it must come from the atmosphere, from the earth, or from both. No earthy substance can ever be received into a plant unless in a dissolved or combined state ; and though crude substances, incapable of assimilation, may in some cases be taken up by the roots of the plant, which seem to have no power of selection in regard to their food, yet they will be exuded from the roots in the state in which they were received. The alkaline substances received and assimilated by plants can only be as-

certained by their ashes after incineration, and constitute a very minute portion ; but, however minute, they are evidently essential to the perfection or fructification of the plant. Besides these there are certain organic acids, which are found in the juices of plants and usually combined with some inorganic bases. The alkaline bases or earths must exist in the soil, or they cannot be found in the plant. In some cases, however, one kind may be substituted for another.

The author discusses at large the doctrine of humus, humin, ulmin, humic acid, apotheme, geine, all referring to one substance, as the food of plants. This matter is generally understood to be a certain brown or carbonaceous substance resulting from vegetable decomposition. Some portions of it are soluble in water or alkalies ; other portions are insoluble but by extraordinary means. The common opinion has been that it constituted directly the food of plants, and required only to be dissolved to be taken up by the roots of the plants and assimilated by them. Others have maintained that it requires to be dissolved by the application of alkalies, and combining with them in the form of an acid, it becomes then prepared for the food of plants. Our author wholly denies these positions by showing that so far from humus being extracted from the soil, it is in fact increased by cultivation, as in the case of a forest, the more abundant the growth of wood upon it, the greater the amount of humus in the soil, where the *débris* of the wood is suffered to remain upon the land.

“ A certain quantity of carbon is taken every year from the forest or meadow in the form of wood or hay ; and, in spite of this, the quantity of carbon in the soil augments ; it becomes richer in humus.” — p. 68.

“ The opinion that the substance called *humus* is extracted from the soil by the roots of plants, and that the carbon entering into its composition serves in some form or other to nourish their tissues, is so general and so firmly established, that hitherto any new argument in its favor has been considered unnecessary ; the obvious difference in the growth of plants according to the known abundance or scarcity of humus in the soil, seemed to afford incontestable proof of its correctness. Yet this position, when admitted to a strict examination, is found to be untenable ; and it becomes evident that humus in the form in which it exists in the soil does not yield the smallest nourishment to plants.” — p. 61.

He attempts to prove his position, that the carbon of the plant cannot be derived from the soil, by a calculation of weights and measures. Humic acid, or the humus of the soil, can only be absorbed by the plant in combination with some inorganic bases or metallic oxide. We do not think it important here to give any thing more than the results of some of his calculations. He supposes that upon an average 40,000 square feet of land, Hessian measure, yield annually 2650 lbs. of dry fir wood, which contain 5.6 lbs. Hessian of metallic oxides. Now it is ascertained in what proportion humic acid combines with the metallic oxides, with lime for example. Having determined the metallic oxides existing in such a product, he easily determines the amount of humic acid thus introduced into the trees ; and, allowing humic acid to contain 58 per cent. of carbon, this would correspond only to the production of 91 lbs. Hessian of dry wood. But 2650 lbs. of fir wood are actually produced. These calculations are well worth examining, and, if accurate, it is difficult to deny the inference which follows from them, that the humic acid existing in a soil, supposing all its carbon to be taken up and assimilated, will supply but a very small portion of that which exists in the crop, grown upon the soil.

The same remarks are applied to a crop of wheat. From the known properties of metallic oxides existing in wheat straw (the sulphates and chlorides also contained in the ashes of wheat straw not included), it would be found, that the wheat growing on 40,000 square feet Hessian of land would average 1780 lbs. Hessian of straw, independently of the roots and grain, and the composition of this straw is the same as that of woody fibre. Now, according to well-ascertained properties, it could receive but $57\frac{1}{2}$ lbs. of humic acid, which would supply with carbon only 85 lbs. Hessian of straw.

Another calculation respects the amount of humic acid which plants can receive through the agency of rain water. The amount of rain falling in one of the most fertile districts of Germany, during the months of April, May, June, and July, is estimated to be $17\frac{1}{2}$ lbs. Hessian upon every square foot of surface, or upon 40,000 square feet Hessian, 700,000 lbs. Hessian of rain water. Now this extent of land averages a product of 2850 lbs. Hessian of corn (wheat) ; 390 lbs. of humic acid calculated to be absorbed in this case, cannot account for the quantity of carbon contained in the roots and

leaves alone, even if we suppose the whole of the rain water to be absorbed by the plants, whereas a large portion of it must necessarily be lost or pass off in some other form than through the organs of the plants. If these calculations be correct, it is evident that a small portion only of the carbon existing in plants can be derived from the humus of the soil. Another idea is suggested, viz. that as humus results from the decay of plants, none existed at the time of the creation to form the pabulum of the primitive vegetation. This must have had other sources of supply. Dr. Dana is of opinion that geine or humus is an original creation, coeval with the creation of hydrogen and oxygen and carbon. The conjecture is sufficiently plausible, but it would be idle to advance any opinion on the subject. The only fact which can be said to favor one opinion above the other, is, that the plants found in the earliest coal formation are plants with small roots and expanded foliage, implying that they drew their chief nourishment from the air.

The inquiry which next arises, is, if plants do not derive their carbon, or but a very small portion of it from the soil, whence is it obtained? This interesting question Liebig discusses at large, and certainly with much ability. The seed itself contains the first supply of nourishment for the roots of the infant germ of the plant. Before it appears above the surface, the humus in the soil quickens and invigorates its growth by the supply of carbonic acid. This supply of carbonic acid is furnished by the accession of atmospheric air from the loosening of the soil, the carbon of the humus combining with the oxygen of the air to produce nourishment for the young plant. When it rises above the surface, and its external organs of nutrition, its stem and its leaves, are fully developed, it ceases to draw nourishment from the earth and obtains all its carbon from the air. It is not a new doctrine that plants absorb carbonic acid from the atmosphere. This fact has been long established; but it is new that this is the principal source; and the inquiry naturally arises whether the atmosphere, containing, as it does, only a thousandth part of carbonic acid, can furnish in this way a supply of all the carbon which is required by the plant. To this inquiry Liebig replies as before, by making it matter of exact calculation.

“It can be shown, that the atmosphere contains 3,000 billion Hessian lbs. of carbon; a quantity which amounts to more

than the weight of all the plants, and of all the strata of mineral and brown coal, which exist upon the earth. This carbon is therefore more than adequate to all the purposes for which it is required." — p. 74.

The absorption of carbonic acid from the air, in his opinion is a purely chemical process. Many others have chosen to regard it as a vital operation ; and have considered the leaves as respiratory organs, resembling the lungs of animals. He does not admit the analogy, and thinks that the cause of science is injured by the supposition of a resemblance, where no similitude exists. The absorption of carbonic acid from the air, the assimilation of its carbon, and the return of its oxygen to the air, are chemical processes, effected under the operation of light and heat. Without the aid of chemistry, they are inexplicable ; with it, they become perfectly intelligible. The vital action creates nothing. It does not produce carbon, oxygen, or hydrogen ; but it puts them into activity ; and they then arrange themselves according to chemical principles ; each organ of the plant having its own specific influence in the production of the results.

The author discusses, at large, the nature and action of humus. Humus is merely decayed vegetable substance, whose decay or destruction is effected by the absorption of oxygen from the air. Exclude it from the external air, and the decay would cease ; but would be renewed again as it should be brought in contact with the oxygen of the air. Woody fibre, in a state of decay, consists of carbon and the elements of water. Alkaline substances assist its decay. Humus, however, is not composed exclusively of woody fibre ; other substances are associated with it. We have not the room to follow Liebig in his curious and profound remarks on this subject, and can only give a summary of his views. The constant tendency of humus is to form carbonic acid by the abstraction of oxygen from the air. The stirring of the soil, and opening it to the effects of light and heat and moisture, assist this process, by bringing it in contact with the decaying humus. It forms around itself an atmosphere of carbonic acid, and supplies carbonic acid to the plant in the first period of its growth. The roots of the plants, in the beginning and before their formation, perform the functions of the leaves. They extract from the soil the carbonic acid generated by the humus. When a plant is matured, and

when the organs, by which it receives its food from the air, are perfected, the carbonic acid of the soil is no further required. Humus does not afford nourishment to plants, by being taken up into their vessels in an unaltered state; but only by the supply of carbonic acid, which it generates from the presence of atmospheric air.

Hydrogen is another constituent of plants; for woody fibre is composed of carbon and the elements of water. Water is decomposed under the power possessed by plants of separating its elements, and of assimilating its hydrogen, and dispensing with that portion of its oxygen not required by the plant in other processes of its growth. Nitrogen is another constituent, found in all plants; abounding in some, and supposed to form the principal portion of the nutritive properties of some of the cereal grains. The nitrogen of the air cannot enter into combination with any element excepting oxygen. The combination of nitrogen with hydrogen, in the proportion of one volume of nitrogen and three of hydrogen, produces ammonia. It is in the form of ammonia, that plants receive their nitrogen. This ammonia is furnished to the roots of the plants by the decomposition of animal matter in the soil, and to their leaves by the effluvia arising from decayed and decaying animal and vegetable substances. This decay is continually going on, and, together with the excrements of animals, supplies the ammonia contained in the atmosphere. There are, indeed, some natural subterranean sources of ammonia, connected with volcanic action; and ammonia is found in many springs, which, Liebig supposes, derive it wholly from the atmosphere. The principal part of the nitrogen, which is found in plants, is, in his opinion, obtained in the form of ammonia in rain water. Though it appears that it has been discovered by others, that rain water contains ammonia, yet it is believed that Liebig has been the first to announce the fact. He goes on to show, by the elements made use of in a former calculation, that by means of the rain falling annually upon 40,000 square feet of soil, the field must receive 80 lbs. of ammonia, or 65 lbs. of nitrogen, which is more nitrogen than is contained in the amount of crops usually produced upon such a surface. The experiments made to ascertain the presence of ammonia in rain water, are decisive, and this interesting fact may be considered as now established. He likewise detected ammonia in the juices of the ma-

ple and the birch tree ; this, being obtained remote from any house, was evidently derived from the atmosphere.

There are facts here connected with cultivation, and showing the effect of different manures upon the quality of the products, which are extremely curious. Different wheats are found to contain very different proportions of gluten, of which nitrogen forms an important constituent. Some French wheat was found to contain 12.5 per cent. of gluten, while Bavarian contained 24 per cent. Davy obtained 19 per cent. from winter, and 24 from summer, wheat. Sicilian wheat afforded 21 per cent. ; Barbary wheat, 29 ; Alsace, 17.3 ; wheat grown in the *Jardin des Plantes* 26.7, and winter wheat 3.33 per cent. In regard to these differences, Liebig remarks ;

“ An increase of animal manure gives rise not only to an increase in the number of seeds, but also to a most remarkable difference in the proportion of gluten, which they contain. Animal manure acts only by the formation of ammonia. One hundred parts of wheat, grown on a soil manured with cow dung (a manure containing the smallest quantity of nitrogen), afforded only 11.95 parts of gluten, and 64.34 parts of amylin or starch ; whilst the same quantity, grown on a soil manured with human urine, yielded the maximum of gluten, namely, 35.1 per cent. Putrified urine contains nitrogen in the forms of carbonate, phosphate, and lactate of ammonia ; and in no other form than that of ammoniacal salts.” — p. 136.

As illustrative of the value of ammonia in vegetation, Liebig refers to *guano*. This is the excrement of sea-birds, and found in large quantities on several islands in the South Sea. The effect of this manure is understood to be most powerful. It renders the soils, which consist of clay and sand, and contain, as is represented, no organic matter, highly fertile. This manure is composed principally of salts of ammonia, and a few earthy salts.

Liebig, if his theory be well founded, has solved the secrets of the operation of gypsum. It has been supposed, that gypsum acted upon plants as a stimulus, or like intoxicating liquids upon animals. But plants are not animals. They have no nerves, which may be tightly drawn or relaxed ; and such suppositions, which serve only to betray our ignorance, are without foundation. No substance can cause the leaves of plants to appropriate an excess of car-

bon from the atmosphere, when the other constituents of the plants are wanting. The influence of gypsum is to fix the ammonia which is brought into the soil, and preventing its evaporation, give it out as the plants may receive it. This effect is produced by the double decomposition of the carbonate of ammonia, and of the gypsum or sulphate of lime, by which sulphate of ammonia and carbonate of lime are formed. His notions on this subject, being the first satisfactory attempt at a solution of the mystery always connected with the application of this extraordinary substance, are curious and interesting.

“In order,” he says, “to form a conception of the effect of gypsum, it may be sufficient to remark, that 100 lbs. Hessian of burned gypsum fixes as much ammonia in the soil, as 6,250 lbs. of horses’ urine would yield to it, even on the supposition, that all the nitrogen of the urea and hippuric acid were absorbed by the plants without the smallest loss, in the form of carbonate of ammonia.” — p. 143.

He is equally original in his explanation of several other facts.

“The advantage of manuring fields with burned clay and the fertility of ferruginous soils, which have been considered as facts so incomprehensible, may be explained in an equally simple manner. The oxides of iron and alumina are distinguished from all other metallic oxides by their power of forming solid compounds with ammonia. Minerals containing alumina or oxide of iron also possess, in an eminent degree, the remarkable property of attracting ammonia from the atmosphere and of retaining it.” — p. 144.

Powdered charcoal is another element, which powerfully absorbs ammonia; and will take up ninety times its volume of ammoniacal gas, which it gives out upon being wet with water. Decayed wood resembles charcoal in this property, absorbing seventy-two times its own volume. This explains further the operation of humus, which supplies not only carbonic acid, but likewise nitrogen, to the growing plants.

A beautiful reflection with which Liebig concludes this chapter, we cannot forbear quoting.

“Carbonic acid, water, and ammonia contain the elements necessary for the support of animals and vegetables. The same substances are the ultimate products of the chemical

process of decay and putrefaction. All the innumerable products of vitality resume, after death, the original form from which they sprang. And thus death, — the complete dissolution of an existing generation, — becomes the source of life for a new one." — p. 147.

The next subject of discussion with Liebig, relates to the inorganic constituents of plants. These are potash, soda, lime, magnesia, oxide of iron, manganese, silica, and other substances. The plants cannot be perfected without them. Alkalies of one kind may often be substituted for those of another ; but they are always found in equivalent proportions. These inorganic substances are admitted to the plants in combination with some acid. They exist independently of the plant, and are not the product of vital action. They are found in different soils, and are the result of the decomposition of various rocks. Potash is an important constituent of most felspars. Some of the salts are evaporated in sea water, and in that way carried far into the interior, and after being spread upon the earth, are carried down by the rains. They are returned to the soil in decayed vegetable and animal matter, and in the excrements of animals. They are found in the ashes of plants in the form of carbonates ; and by careful analysis their amounts in different cases have been accurately ascertained. The amount of alkaline substances required by plants is very minute. But that amount is requisite to the perfection of the vegetation. It is easy to conceive how small an amount is required in the soil, when it is understood that sea water contains only $\frac{1}{12400}$ of its weight of carbonate of lime, and yet that is sufficient for the formation of all the banks of coral in the ocean, and the various shells of the marine animals.

Having given this account of the constituents of plants, and the sources whence they are derived, Liebig proceeds to discuss the art of culture and the action of manures. We should be glad to quote the whole of this chapter, but we must limit ourselves to a brief sketch. Humus is not soluble in water ; if it were, a great part of it would be carried off the ground by rains. Its office is, by the presence of water, to convert the surrounding oxygen into carbonic acid, which plants absorb and then return to the soil a large portion of carbonaceous matter, that they abstract from the air, so that

the humus of the soil is not diminished. The frequent ploughing of the soil, so as to promote, by admitting the oxygen of the air to the humus, the formation of carbonic acid, the application of alkaline substances, and whatever tends, as Liebig expresses it, to put the organic matters of the soil in a state of oxidation, increase the fertility of the soil. The oxygen then assists in the formation of carbonic acid to go to the nourishment of plants.

Knowing the substances which go to form the plants, the object of a wise agriculture will be to supply them, and to render them accessible to the plants. Potash, the most common and important of the inorganic constituents of plants, is more universally and abundantly diffused over the earth than any other alkaline substance. But the alkalies, by continual cultivation, may be exhausted, and the soil cease to be productive. This indicates the necessity of a fallow or rest to the soil, by which, under the operation of air and moisture, a further disintegration of the rocks may take place so as to furnish the necessary alkalies to the soil, or, without resting, they may be artificially supplied. Plants themselves in their decay return alkaline substances to the earth; and it is well ascertained that plants themselves act powerfully in the disintegration of rocks.

Some crops may be repeated on the same soil more frequently than others, because some consume more of the alkalies than others. One hundred parts of the stalks of wheat yield 15.5 parts of ashes; The same quantity of barley, 8.54 parts; and of oats, only 4.42. The ashes of these different plants are of the same description, but it is obvious that the demands which they make upon the soil must be different.

The interchange or rotation of crops and the application of manures are materially connected with this fact, and with another in the habits of plants to which we shall refer. Plants of different kinds absorb or take up different substances, from the soil; and one kind therefore may flourish, where another would fail. The same kind of plants cannot be cultivated in succession on the same soil for any length of time without declining in productiveness. Some plants, as flax for example, will not bear a repetition on the same soil oftener than once in five years. It has been supposed that plants assimilate to themselves, and consume in their growth, certain ingredients in the soil necessary to the perfection of

the plant, which should not be repeated on the same ground until this material is again supplied. But this is not all. No artificial supply of any ascertainable ingredient can control this general law of the necessity of a change in the rotation, growing out of other circumstances. Decandolle suggested, and may be said to have established, another theory, namely, that plants excrete from their roots certain substances, which are innutritious or hurtful to the same kind of plant in succession, but which may serve as the food of other plants. But there are difficulties, in respect to this subject, upon which we cannot dwell, which Liebig's theory solves with remarkable ability and equal reasonableness. The exudations or excretions of plants may be considered of two kinds. Plants, as we have before said, have no selection in their food but take up with little discrimination what is accessible to their organs of nutrition, and in a condition to be absorbed. They consequently may take up many things, which they can assimilate but in part, or not at all. These are exuded, and may serve as the food of other plants of a different character. But there is another class of excretions, or properly speaking excrements, which are purely the result of the vital action of the plants, and which, in the form of gum or otherwise, after having served the purpose designed in the nutrition of the plants, pass off by the appropriate organs into the soil. These, of course, cannot serve as the food of the same kind of plants, or of any other in their present condition ; and these go to assist in forming the humus of the soil. In their unchanged condition, these excrements are pernicious to the kind of plants from which they were discharged, and, it may be, to others ; but after becoming converted into humus, under the operation of air and moisture, the effects are the same as those of humus.

After all, where the crops are removed from the soil in the forms of seeds, roots, and leaves, the soil is of course deprived of many of the constituents requisite to a healthful and productive vegetation. The substances removed are then to be supplied by manure. The seed of the plant contains within itself the food which it first requires in order to the protrusion of its radicles. The humus in the soil will give out its carbonic acid, until the plant rises above the ground, and the leaves and other portions of its organism are formed, to enable it to gather, in the form of carbonic acid,

its food from the air. Its inorganic constituents must be found in the soil or in the manure in the form of silicates, carbonates, or phosphates, and may be supplied in a crude form as in potash, ashes, lime, bones, &c. Its nitrogen is to be supplied, in the form of ammonia, from decayed animal or vegetable substances in one way or another. The excrements of some animals are in this respect much richer than those of others. The excrements of man are much richer in nitrogen, than those of any other animals, and those of men living upon animal more so than those of men living upon vegetable diet. In the urine of animals nitrogen is found in much greater abundance than in the solid excrements. In respect to nitrogen, 100 parts of the urine of a healthy man are equal to 1300 parts of the fresh dung of a horse. This ammonia is supplied in the soil; or floating in the air, it is taken up by rain water or by snow, and supplied to the vegetation in that form. The manures of different animals likewise return to the soil the inorganic constituents of plants, the various salts which have formed a part of the vegetable products, which have been taken from the fields and been consumed by the cattle; and thus every thing goes on in an eternal round of reciprocity.

We have thus given a general and imperfect sketch of the main principles of the work of Liebig. We have confined ourselves to the part, which is principally agricultural. The second part, on chemical transformations, fermentation, putrefaction, decay, and various kindred subjects, is equally interesting; but we cannot now examine it. We regard the work of Liebig as a work of extraordinary philosophical acumen, and conferring upon him the highest honor. The more it is examined, the deeper will be the interest which it will create, and the stronger the admiration of the ability with which it is written. It is not a work to be read, but studied; and if further inquiries and experiments should demonstrate, as seems to us from many facts within our own knowledge in the highest degree probable, the soundness of his views, his work, not merely as a matter of the most interesting philosophical inquiry, but of the highest practical utility, will be invaluable.

We are much indebted to Dr. Webster for giving this handsome edition to the public, enriched with several valuable notes. We could have wished that the introduction, intended as explanatory of the general principles of chemistry,

compiled from another work of Liebig, and designed to assist the unlearned reader, had been appended instead of prefixed ; for either from an inherent fault of expression, or from badness of translation, some portions of it are so intensely obscure (witness for example the 129th and 195th paragraphs among many others), that it must operate as a great discouragement to the perusal of the main work with many persons, serving as it now does, instead of an explanation, in some cases only to render darkness visible.

There are various notes, appended to the volume, of great interest. It is mentioned that Mr. Hayes, who stands in the foremost rank among our practical chemists, had discovered the presence of ammonia in the rain waters in Vermont ; but it does not appear that he had given the fact to the public. A long and highly interesting note is appended, containing some letters from Dr. S. L. Dana, of Lowell, to Dr. Hitchcock, of Amherst College, and taken from the forthcoming third edition of Dr. Hitchcock's "Geology of Massachusetts," on geine or humus, and some views of Dr. C. T. Jackson, of Boston, on the same subject.

The views of these gentlemen in some measure conflict with each other, and with those of Liebig. We do not propose to arbitrate between them, but only to remark on them, in a very few words, with a perfect respect for all the parties concerned. The eminent Swedish chemist, Berzelius, had discovered in several vegetable substances, a residuum, which he regarded as the proper food or pabulum of vegetables, and which he denominated *humus* or *geine*. Dr. Dana, by his independent researches, had arrived at the same result. This geine or apotheme was found to be the uniform result of decayed vegetation ; and soils are in general found productive or otherwise, as this vegetable substance or residuum is more or less abundant in them. The opinion of Dr. Dana has been that geine in a dissolved state is taken up as the food of plants. If obliged to relinquish this ground, and with Liebig, regard geine as only a source of carbonic acid to plants, he would regard its value to vegetation in the same light. But he obviates in a most ingenious manner one of the difficulties of Liebig, in respect to the solubility, or, we may more properly say, the solution of geine, by showing that it contains within itself the instrument, to a considerable degree, of its own resolution, in the water formed by the union of the hydrogen of

the geine with the oxygen of the atmosphere. "The amount of water produced in this case," he remarks, "is truly astonishing. It has been found equal per hour, from an acre of fresh ploughed sward, to 950 lbs. This is equal to the evaporation per hour from an acre, after most copious rains. To show that this depends upon the decomposition of the geine, the quantity of water evaporated per hour in the day time, from a well-manured acre, was found equal to 5000 lbs."

That humus or geine does not constitute the actual food of plants would seem to be established by various considerations. Liebig has shown by several calculations, as exact as the nature of the case would seem to admit of, that the amount of humic acid contained in any soil is insufficient to supply the carbon in the average product of that soil, in the proportion of 91 to 2650. Secondly, volcanic salts, containing not the slightest trace of vegetable matter, as is evident from their origin, with a due mixture of earths are among the most fertile in the world. The ashes being exposed to air and moisture, a soil is gradually formed, and the decomposed lavas furnish alkalies in abundance, which, by being exposed to air and moisture, become the source of rich nourishment to plants. A third reason, and certainly a strong fact in the case, is, that the humus in a forest, so far from being diminished by the growth of wood, is continually increasing. It is so, likewise, in a cultivated field, where the produce of that field is returned in the form of manure.

Berzelius is reported to have altered his opinions of the nature of geine, by a more exact analysis of its composition, and now denies its existence as a proximate principle; and Dr. C. T. Jackson, who has distinguished himself as a chemist by his analytical researches, appears to have made, without knowing what had been done by Berzelius, the same discoveries, in ascertaining that the substance called geine is only a combination of crenic and apocrenic acids, with some other substances, all of which are not yet determined. How many of these may have been, as suggested by Dr. Dana, the mere product of chemical manipulation, or whether any of them, are questions, which, in the present state of the inquiry, cannot be determined. Upon the supposition that these are original and fixed elements in the composition of geine, we consider Dr. Jackson entitled to much honor for his investigations. All truth is valuable; but, in the present condition of our knowledge, in

a practical view, these points are not of great importance, or rather not of immediate utility. According to the principles of Liebig, Raspail, Dana, Jackson, Hitchcock, and others, the presence of humus in a soil is, *quoad hoc*, an indication of fertility. Now, whether it be a proximate element, or a mere combination of crenic and apocrenic acids with other substances, though exceedingly interesting to the philosophical inquirer, is, without some further light on the subject, of little moment to the farmer. Dr. Jackson has not, as we understand, discovered either of these acids in the plants themselves; he has not shown us how they are to be used, or what part they perform in vegetation. He is not able by any artificial process, which he can adopt, separate from the vegetable organism, to produce an atom of geine; and, however nearly he may have approached it, and we commend him for every step in his progress, he has by no means reached the *ultima Thule*; for crenic, and apocrenic, and ulmic acids, are themselves resolvable into certain proportions of carbon, hydrogen, nitrogen, and oxygen. The question, however, whether geine constitutes in itself the food of plants, in its solution by water or by some alkaline substance, or whether it merely acts as an instrument of the supply of carbonic acid to the plant in the first stages of its progress, is another question, which is certainly not without its difficulties. We are not able to understand by what process it is ascertained, that, after the leaves of the plant are formed, it ceases to draw any nourishment from the earth. This is a fact in vegetable physiology, of which at present we are without the proof. Dr. Dana has never denied that plants receive much of their nourishment from the air. His inquiries were limited wholly to what they gather from the earth. Nor do we see any difficulty in the supposition that geine may serve, in its decomposition, as the food of plants. For, if geine, according to Dr. Jackson, is a mixture of crenic or apocrenic acids, and if crenic and apocrenic acids are resolvable into carbon, hydrogen, nitrogen, and oxygen, these are the very elements of vegetable substance; and we may leave it to the subtle operations of that vital action, wonderful and mysterious as it is in its operations, to accomplish what human skill and sagacity have as yet in vain essayed, the separation and appropriation to itself, by the living plant or animal, of the proper materials of its own growth.

It is exceedingly gratifying to see men of science engaging

in these, we will not say humble, for scarcely any are more important, but useful subjects of investigation. Every department of nature abounds in matters of interesting inquiry ; and none more than that of organic life. Nature in her various changes, transformations, and productions, is everywhere full of the miracles of wisdom, power, and goodness. The perfections of the Creator are written all over her in letters of living light. The highest duty of rational beings is " to read, mark, learn, and inwardly digest them."

In looking at the infinitely multiplied productions of the vegetable world, in observing a small seed rising into a towering plant, an acorn changed into an oak, and what seems a minute pellicle, driven about by the wind, growing up into a mighty and wide-spreading elm, we must be lower than the beasts, which repose under its grateful shade, if we do not ask, How can these things be ? When we see the earth in a measure obedient to our commands, and in return for our labor pouring into our laps the means of subsistence and luxury with an unstinted liberality ; when we see the dependence everywhere existing between what we do and what we receive, what we sow and the harvest we gather ; when we observe the changes of the seasons, and the obvious effects of light and heat, and moisture and manure, we can hardly claim the character of rational beings, if we do not seek to understand how these things are. It is idle to pretend that the mysteries of nature are too sacred for inquiry. The gift of understanding and the power of its use imply the duty of inquiry. It is as idle to pretend, that they are mysteries which never can be understood. The human understanding has its limits, doubtless, beyond which it cannot pass ; but how far is it at present from having reached them ? Every day is disclosing to us some new truth. Many things, once enveloped in all the terrors of mystery, are now familiar to the understanding of a child. The works of God and the courses of his providence are not so many isolated facts, but they are facts compacted together, and under the control of general laws ; so that beyond all question, many of the most extraordinary phenomena, which present themselves in nature, are explicable upon the simplest principles. In many cases a single key will open the most complicated lock, and is at the same time applicable to a thousand others. The discussions of Liebig furnish some beautiful illustrations of these principles.

In order to solve the secrets of vegetable life and growth, we must watch the plant from its germination to its maturity, and remark, with all possible exactness, the various influences which bear upon it. We must study its nature, its relations, its changes; its relations to the soil, to the climate, to the light, to the moisture, and to its whole culture. Botany, considered as a mere form of classes and a mere catalogue of arbitrary names, is a meagre and comparatively worthless science; but, when it involves the whole physiology of plants in all their aspects and conditions, in their growth, culture, maturity, and uses, it becomes a profound philosophy. Chemistry, likewise, must here come to our aid. In order to know what the plant needs, we must know what it is composed of; in order to learn what it obtains from the soil, we must ascertain what the soil has to yield to it; and we must consider the condition of the plant, in reference to the condition of the soil in which it is planted. Manures, likewise, everywhere the acknowledged means of fertility, require the most exact examination. Ascertaining, by the aid of chemical inquiry, the elements of the plant, we shall at least learn something of what it requires; ascertaining the nature of the soil, we shall see how it is suited to the plant cultivated; and knowing the composition of the manures, we may come to understand their operations. Chemical analysis seems to offer the only means of solving these mysteries.

It has already made distinguished advances; but yet they can be regarded only as first steps. There are difficulties in the case, which it would be in vain to deny. All chemical analyses are necessarily destructive of the subjects to which they are applied. We cannot take the separate elements from the analysis of a plant, a manure, or a soil, and put them together again like the pieces of a dissected map. We can easily infer from a thousand facts, which chemistry has already disclosed, how much depends upon the form of combination of the most simple elements; and when we consider of what an almost infinite number of permutations and combinations a few simple substances admit, we perceive difficulties in the nature of the case which must certainly very much qualify our confidence of success. They should at least check all haste in our conclusions, and disarm all severity of judgment in respect to the conclusions of others, how much soever these may differ from our own. Truth

should be our great and only object. Philosophy stimulates to the pursuit of it as the most precious of all gems. Nothing should abate our zeal ; nothing should discourage our efforts in the search. Fifty years ago chemistry was hardly known as a science. Now, what triumphs has it accomplished, and what a world of wonders has it opened to our view ! In its application to agriculture it presents itself as the natural solvent of its now difficult mysteries ; its whole tendency and aim, in this matter, unlike many other of its applications, is to confer unmixed good upon mankind. It discloses to our adoration more and more of those mighty operations of a beneficent Providence, by which, in an unbroken circle of dependence and subserviency, the most offensive substances are converted into all that is nutritive, delicious, and beautiful. It shows us how, by the exact and wonderful combination of a thousand subtile influences in the earth, the air, the rain, the light, the dew, daily and hourly the table of the Divine bounty is spread for all that live ; and not one of his great family is, by the master of the feast, ever sent empty away.

ART. VII. — *Tragedie ed altre Poesie* di ALESSANDRO MANZONI. Settima Edizione. Parigi. 1830. 12mo. pp. 487.

IN our Number for last October,* we gave some account of Manzoni's celebrated novel, "I Promessi Sposi." We took no notice of the poetical performances of this most distinguished living poet of Italy, except that in a note at the close we made a slight allusion to what he had done in this his favorite department, and ventured to call his "Ode upon Napoleon," the finest that has ever been written upon that most attractive but difficult subject. We propose at present to add a little to that allusion, and to say a very few words upon those tragedies and shorter metrical pieces, upon which his fame as a bard has been established.

The genius of Manzoni, melancholy, contemplative, tender, is specially suited to the ode, and to those subjective compositions, in which the sentiments and feelings of the

* See *North American Review*, Vol. LI. pp. 337 *et seq.*